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MEASUREMENTS OF THE COMPOSITION OF AEROSOL COMPONENT OF VENUSIAN ATMOSPHERE WITH VEGA 1 LANDER. PRELIMINARY DATA

Yu.A. Surkov, V.F. Ivanova, A.N. Pudov, V.P. Volkov, E.P. Sheretov, B.I. Kolotilin, M.P. Safonov, R. Thomas, J. Lespagnol, A. Hauser, G. Israel, D. Imbault and D. Caramelle

Translation of "Izmereniye sostava aerozol'noy komponenty atmosfery venery na AMS "Vega-1". Predvaritel'nyye rezul'taty", Pis'ma v AZh, vol. 12, No. 2, 1986, pp. 110-113.

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16. Abstract
Preliminary investigation of mass spectra of gaseous products of pyrolyzed Venusian cloud particles collected and analyzed by the complex device of mass-spectrometer and collector pyrolyzer on board the Vega 1 lander revealed the presence of heavy particles in the upper cloud layer. Sulfur is the main chemical component of the cloud particles. Based on 64 a.m.u. peak (SO_2^+), an estimate of the lower limit of the sulfuric acid aerosol content at the 62-54 km heights of ~2.0 mg/m^3 is obtained. A chlorine line (35 and 37 a.m.u.) is also present in the mass spectrum with a lower limit of the chlorine concentration of ~0.3 mg/m^3.

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MEASUREMENTS OF THE COMPOSITION OF AEROSOL COMPONENT OF VENUSIAN ATMOSPHERE WITH VEGA 1 STATION. PRELIMINARY DATA

Yu.A. Surkov, V.F. Ivanova, A.N. Pudov, V.P. Volkov, E.P. Sheretov, B.I. Kolotilin, M.P. Safonov, R. Thomas, J. Lespagnol, A. Hauser, G. Israel, D. Imbault and D. Caramelle[1]

Investigations of the global cloud cover of Venus have been conducted in a goal directed way in the USSR and USA with the help of space means for more than 10 years. A generalization of the results of the investigations showed in particular that the Venusian clouds have a zonal three-layered structure (Hunten et al., 1983; Volkov, 1983). Their upper boundary is at an altitude of 68-70 km and their lower boundary at an altitude of 47-49 km from the surface of the planet. /110*

Cloud particles are basically droplets of liquid aerosol with mass densities on the order of 10 mg/m^3 (Hunten et al., 1983); this is 50 times less than in the earth's clouds. It has been established that the cloud condensate is characterized by a trimodal distribution of its particles by dimension. Aerosol of mode 1 (r=0.15-0.25 μm) is a liquid droplet polycondensate and it evidently contains an inclusion of solid particles, mode 2 (r=0.9-1.4 μm) is identified with spherical liquid drops with a very narrow interval of distribution by size. According to the results of measurements of the number of cloud particles with the help of laser spectrometers on the "Pioneer-Venera" probes (Knollenberg et al., 1980), it was concluded that /111

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* Numbers in the margin indicate pagination in the foreign text.

large solid mode 3 particles (r=3-4.5 μm) are present in the middle and lower cloud layers. However, later these results were the subject of criticism (Toon, 1984), and the authors of the experiment, dismissing the identification of large particles, recognized their conclusions on the crystalline nature of the particles to be in error (Knollenberg, 1984).

An analysis of extensive material on the physics of the Venusian atmosphere allowed A. Young and G. Sill even in 1972 to advance the hypothesis that the Venusian clouds are composed of droplets of liquid aerosol of concentrated H_2SO_4 (Young, 1973; Sill, 1972). Actually, with the help of roentgen fluorescent analyses of cloud particles sampled from the middle cloud layer on the lander (LV) "Venera-12" and then on LV "Venera-14", it was possible to detect sulfur (0.2 mg/m^3), however in addition to this, chlorine was found (Surkov et al., 1981, 1982). The forms in which both of these elements were found were unknown until then. According to data from physical-chemical calculations, drops of concentrated H_2SO_4 and solid or liquid condensates of elemental sulfur are considered the most real sulfur containing components of the cloud layer (Hunten et al., 1983; Volkov, 1983). There are several hypotheses concerning large mode 3 particles: drops of H_2SO_4 (Toon, 1984), $HClO_4$ (Sill, 1983), or $NOHSO_4$ crystals (Watson et al., 1983). The form in which chlorine is found is also the subject of discussion (Volkov, 1983; Sill, 1983).

In order to determine the chemical composition of the cloud particles on the LV of AMS "Vega-1", a device was installed which collects aerosol, separates particles according to mass, runs pyrolysis and does mass-spectral analysis of each fraction separately. The sampler of the device was hermetically sealed during the entire flight to Venus. After the station entered the planet's atmosphere and the parachutes were opened, the sampler was depressurized with the help of a pyrotechnical device and the intake for gas with aerosol into the collector-pyrolyzer was opened. The atmosphere being

sampled was pumped by a ventilator through a chamber of the separator where the inertial separation of particles into two fractions, light and heavy, was done. The separation boundary (r=1.5 μm) was established during calibration of the separator using monodispersed particles with density 1.4 g/cm^3. Both groups of particles were collected on separate filters which were subjected to pyrolytic heating (T=400°C). The pyrolysis products went into a mass-analyzer through an injection system. A gas flow of not more than 10^{-5} liters·c^{-1} was ensured through the inflow.

In order to maintain a vacuum in the analytical section, the device had two pumps - a getter pump which pumps CO_2 before gas is fed from the collector into the mass-spectrometer, and a magnetic ionizing pump which is connected to the mass analyzer and which pumps the gas going into it. /112

In the device a hyperboloid mass-analyzer which was a three-dimensional catcher assembled on an axially symmetrical lens was used. Its operating principle is based on the ability of high frequency electrical fields with a permanent component with a quadratic potential distribution to separate ions with respect to specific charge. The analyzer is a system of three field-forming electrodes, a ring one and two face ones, which are rotational hyperboloids and which form a closed volume. In this volume occurs ionization of molecules of the gas being studied with pulsating electron beams going into it and sorting of the particles by size m/e with their subsequent discharge into a recording device. During the manufacture of the flight model, several nodes of the mass-spectrometer were duplicated (the electron source and the microchannel assemblies). In order to satisfy requirements on resistance to vibrational and impact overloads under the conditions of space flight, in manufacturing the electrode system a special nonadjustable technology based on the principle of electrolytic formation was used. The analyzers made according to this technology ensure minimal shifts of the electrodes under the effect of mechanical stresses. The sweep of the mass

spectrum from 10 to 150 amu is done by changing the frequency of high frequency voltage. The use of frequency sweep ensures continuous sensitivity over the entire mass range. The dynamic range of the mass-spectrometer is $\sim 10^6$. In order to detect ions, microchannel sheets and an impulse preamplifier with a threshold input were used. The ions are counted by a counting-coding device with a microprocessor.

Simultaneously with the scientific information, 22 parameters which control the operation of the device are transmitted on the TM channels. An anomaly was recorded in the behavior of the DCP (discharge current of the pump) parameter. At the beginning of measurements, its value exceeded the maximum permissible value. A decrease in the DCP began 5 minutes after the beginning of operation of the device and attained a nominal value by the end of the experiment. For this reason, some of the spectra recorded at high pressure in an ion source could not be deciphered.

In analyzing the mass-spectra of heavy particles collected in the upper cloud layer at an altitude of 62-54 km, a peak was observed at 64 amu, the presence of which may be explained by the presence of sulfurous anhydride in the pyrolysis products. The relative value of the SO_2^+/CO_2^+ peak was $(3\text{-}4)\cdot 10^{-3}$.

Taking account of losses during the collection of aerosol on the filter, conversion into the gas phase during pyrolysis, absorption in the gas intake system and the calibrated coefficients of the mass-spectrometer, an evaluation was done of the lower boundary of the H_2SO_4 concentration in the aerosol. It is 2.0 mg/m^3.

In the spectrum there are also lines at 35 and 37 amu which belong to chlorine. The peak of the basic isotope ^{35}Cl is $(0.8\text{-}7.0)\cdot 10^{-3}$ and for isotope ^{37}Cl, $3\cdot 10^{-4}$; this corresponds to the lower boundary of the chlorine concentration (0.3 mg/m^3). The value obtained agrees with the estimate of the mass density of aerosol made /113

up of drops of H_2SO_4 in the upper cloud layer according to results of measurements on the "Pioneer-Venera" probes (Knollenberg et al., 1980).

Thus, the mass-spectrometric determination of the chemical composition of aerosol on the "Vega-1" LV showed that the predominant component of heavy cloud particles is sulfur; this is probably present in the form of liquid aerosol of H_2SO_4 or another condensate which is separated during heating with the release of sulfurous anhydride.

An analysis of the mass-spectra of the liquid aerosol fraction and refinement of the results presented will be done later when supplementary calibration work is done.

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